Low-Flow Fume Hood: Baffles and Vortices

Summer Research Report
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Introduction

The nature of this report is to communicate to my mentor, Geoffrey Bell, P.E., the course of my research during my stay at Ernest Orlando Lawrence Berkeley National Labs. As such, its focus will be threefold: first, to describe the state of affairs concerning the low-flow fume hood project when I first arrived at LBNL; second, to outline the research I performed while I was at the lab, and in which directions I helped take the project; and third, to describe my perceptions and predictions of where the project will go in the future.

Initial Conditions

I came in knowing very little about fume hoods, and even less about fluid dynamics (having never taken a course in the subject). My first week, then, was essentially geared towards reading up on the subject of fume hoods, reviewing a bit of the theory behinds Reynolds numbers, and most importantly, getting up to speed on where the project was. Geoffrey had a well-documented record of all the progress up to date, and I took advantage of it. Records were kept in a notebook containing:

- Copies of CFD runs 1-24 with hand-sketched notes on the various baffle setups and fan speed configurations written by Geoffrey.
- A thorough set of screens and mesh specifications, with invoices and other documentation of the screens Geoffrey had already purchased and received. This included a significant section on the Johnson Screens (which had at that point not yet been ordered) including a few AutoCAD drawings.
- A large section of documentation on the various types of fans available to us for order, including several which Geoffrey already had in his possession, ranging from 55 cfm to 200 cfm strength.
- Thorough design notes and sketches regarding the plenums and hood dimensions, produced by Geoffrey.
- Information on the SAI Helium Bubble Generator which we eventually purchased.
- Notes on the Schlieren System, a potentially useful tool in helping us visualize airflow through the hood.
- The ASHRAE guidelines for ASHRAE-110 testing, along with the results and documentation of the test when it was performed on the original low-flow fume hood by Ratcliff & Associates back in March of 1998.

Aside from the extensive amount of communications performed regarding patent information, the above outline details much of where Geoffrey had taken the project since completion of the ASHRAE-110 testing in 1998. He had taken a frame from LBNL's industrial partner, LabConco, and modified it to the design specifications he had logged in the aforementioned notebook, and bought most of the needed materials & tools we would need for the summer. A thorough set of pictures taken with the digital camera can be accessed through the Building 63 computer's hard drive—these catalogue the initial setup of the hood, complete with the environment, movies, and pictures of the baffles. They are currently in the folder entitled "Initial Setup" under the "Fumehood" directory.

Here's one of many pictures of the initial setup.

My Work

My work was defined to be focused on the analysis of the upper vortex and optimization of the baffle configuration within the hood. However, looking back on the past 10 weeks it is clear to me that my work covered many more aspects of the project than just those two areas. I enjoyed being able to perform a variety of tasks as they came up, although in retrospect it did seem to make my path a bit more hazy and less neatly-defined. However, that seems to have been the general style of research for me this summer—as I told Geoffrey once in a casual conversation, I think that whereas Mike did more "engineering" (complete with numbers, calculations, and graphs), I did more "science," as the nature of my tasks was quite a bit more qualitative than quantitative. That being said, here is a summary of the work I performed on the low-flow fume hood project this summer:

CFD Modeling

Part of my responsibilities was to interact with Chris in determining the dimensions with which to conduct the new CFD runs. Our goal was to find a 2-dimensional setup which would eliminate the bottom and top vortices. From this we would then be able to make a direct attempt at physically arranging the baffles and fans to confirm the theoretical result.

Summary of CFD Runs 25-36

Run #	Comments
25	Run #22 + remove slot B
26	Run #25 + remove slot A
27	Run #22 + extra slot betw. E and D.
28	Run #22 + slot E doubled & moved 50% down.
29	Run #19 + fan #2 @ 75cfm, fan #1 @25 cfm
30	Run #17 + enlarge (2x) slots A & C.
31	Run #17 + increase input air #5 to 120 cfm
32	Combine runs #30 and #31
33	Run #12 + enlarge (2x) slots B & C.
34	Run #12 + increase fan #5 to 120 cfm.
35	Combine runs #33 and #34
36	Run #13 + fan #1 @ 40 cfm, fan #2 @ 80 cfm.

Unfortunately none of these new attempts was successful in achieving containment or in eliminating the vortices. However, they were indeed helpful in increasing our understanding of the airflow problems within the hood, and surely helped us as we progressed towards a physical solution to the vortices problem.

Baffle Arrangements

A lot of my work consisted of playing around with cardboard and tape, looking for the best baffle system to move air through the hood in such a way as to avoid spillage and stagnation (LEL concerns), maximize stability against changes in outside (environment) conditions, and maximize re-capture capabilities.

My experimentation consisted of numerous trials:

Experiment	**Observations**
Replace solid back angled baffle with one w/ holes cut out in it (1)	Little effect on airflow patterns at all. No significant change in vortex behavior.
Replace solid back angled baffle with one w/ slots cut out of bottom (2)	Slightly better draw through now-larger slot, but nothing significant.
Tape off middle slot (3)	Increases suction from bottom slot—good for improving floor sweep.
Tape off all gaps between panels and sides	Airflow becomes stagnant in side-back

of hood (3)	corners, small vortices form on sides. Not good.
Change angle of upper baffle piece to expose part of exhaust hole (4)	Good suction out of the top of the hood, while maintaining suction from behind baffle plates.
Add angled plate to front section of hood, to cover exposed superstructure (5)	Keeps air from rolling through superstructure, but doesn't eliminate vortex.
Enlarge front angled baffle piece to block off unused airspace from top of face to front edge of exhaust hole	Vortex essentially eliminated when combined with partially exposed exhaust hole. All air in top of hood evacuated.
Installed small (1.5") horizontal airfoil at top edge of top screen, inside hood	Good repulsion of vortex from face—keeps the roll in the top of the hood
Lengthened horizontal airfoil to 2.5"	Better repulsion of vortex, keeps it even higher and farther from face of hood.
Installed small angled (45 degrees) airfoil at front edge of bottom screen	Helps direct air into the hood better, but allows air that flows outside its "cone of vision" to escape outside the facial plane.
Installed small (1") vertical airfoil in front of top edge of front screen (6)	Air curtain at face of hood seems to be strengthened, although recapture abilities seem to be impaired.
Replaced bottom baffle plate with perforated board	Eliminates problematic roll at bottom of hood!
Redesigned top and front screen profiles: gave front screen quarter-circle profile, and gave top screen flat section w/ half-circle profile facing inwards (7)	Improves containment, reduces vortex to small, insignificant roll that eventually evacuates through exhaust duct. Negates need for horizontal airfoils at top screen.

(1)

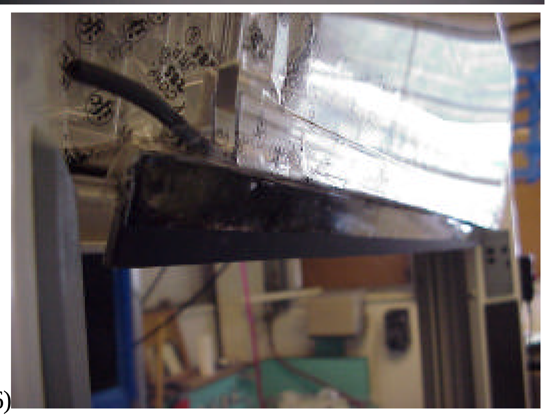
(5)

(3)

(4)

(7)

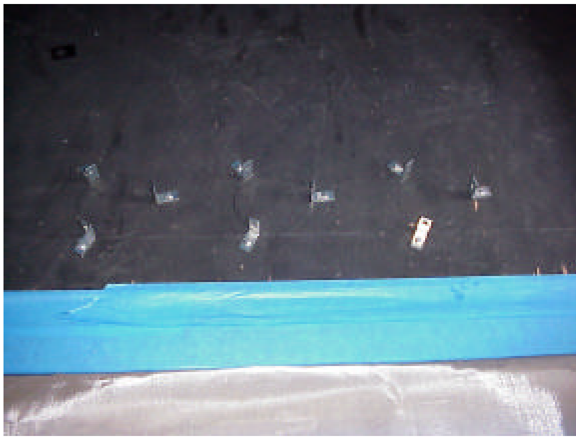
(6)



ASHRAE-110

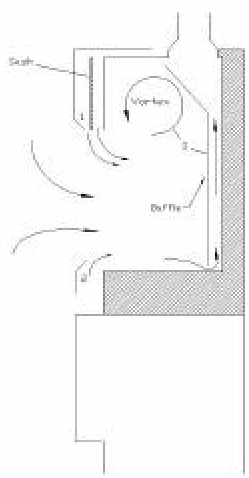
A significant portion of my time was spent in preparations for and conducting of the ASHRAE-110 test. A summary of my duties:

- Collaborated with and assisted Doug in his spearheading of the testing process.
- Contacted Mike Ratcliff to learn more about his testing procedures on the original
- Contacted various companies with regard to SF6 detectors, in an attempt to determine our best option for purchasing/renting a detector.
- Pressure-tested the hood, ductwork, and plenums. Sealed all leaks possible with weather stripping and/or caulk.
- Prepared apparatus for testing—installed mounting brackets, height adjustments to mannequin, calibration of velocity meter.



Miscellaneous

- AutoCAD reproductions of design sketches for communication with consultants such as ATMI, PG&E, etc.



Accomplishments

What did all this work, all these trials, all these various tasks and duties performed lead up to? That is essentially the most important issue—what was accomplished this summer. Well, here is a summary of where I think we got to by the end of my stay:

We now have a hood that passes our in-house version of the ASHRAE-110 SF6 tracer gas containment test. Although our detection instrument does not adhere to the ASHRAE designation of one sampling every 10 seconds, we were still way below the 1 ppm goal, and that is highly encouraging. Something still needs to be done about the background level of SF6 in the room, but the most important thing is that we have a hood setup which we know achieves good containment.

The back and upper angled baffle plates (complete with perforated bottom panel, taped off middle and top horizontal slots, and taped off sides on the middle panel) all seem to have worked quite well throughout our many tinkerings with screen profiles, fan speeds, and airfoil experiments. What this tells me is that the baffle setup I'm leaving the hood with is good, consistent, and stable. It reduces the upper vortex to a small insignificant roll that does not leak out into the face or breathing zone, and does not impede the air flowing in the top of the hood from becoming evacuated out the top. The bottom roll is all but gone, now that we have a perforated bottom baffle plate and taped-off middle slot. Floor sweep is satisfactory, and the sidewalls of the hood are also well-swept as air moves through the hood. It may be worthwhile to try other arrangements (like the inwardly staggered system we had discussed earlier this summer and never got around to) but I see that as a lower priority to be considered as final performance optimizations become ready to be made.

The major issue right now is the plenum designs. The lateral distribution on the bottom plenum is far from uniform, and in some sections there is actually a reverse flow back into the screen. Mike is currently conducting extensive tests trying to determine how to best distribute the airflow laterally. If the plenum designs can be optimized, then I do believe we will have a satisfactory physical arrangement on the hood, and all that will remain will be to optimize the fan speeds to ensure that their performance coincides with that of the physical setup. From there, we should be able to have some official ASHRAE-110 testing done, and then we can move towards implementing our hood in the pilot programs in University of Montana and perhaps University of California at Santa Barbara.

What's Next

Tasks to perform include:

HIGH PRIORITY

1. Take a close look at lateral airflow distribution within top and front plenums—what we discovered in the bottom plenum could very well be occurring in those two as well.
2. Finalize all 3 plenum designs for optimized lateral distribution of airflow. Consider changing placement of fan inlets on plenums, if distribution cannot be achieved with current positioning.
3. Optimize fan speed configurations—test performance envelope for containment, stagnation, re-capture, and resilience against changing room conditions.
4. Test performance of hood with more precisely selected fans (55 cfm at bottom, 75 cfm at top and front?) once plenum modifications and fan speed optimizations are completed.

MEDIUM PRIORITY

5. Utilize CFD modeling to confirm containment/performance of final setup
6. Experiment with alternative baffle systems: staggered back plates, different free hole area perforated bottom plate, etc.

7. Obtain velocity meter readings at numerous positions behind baffles, especially the bottom perforated one. This will allow a quantifiable idea of the airflow behind the baffles to be obtained.

LOW PRIORITY

8. Utilize Schlieren system (if available) as another tool to visualize flow within the hood.
9. Install Pitot tube into the narrow section of the exhaust stack outside Building 63. This should allow for more accurate pressure readings across the exhaust fan.
10. Install fan into one of the walls of Building 63, to allows us to create a slight yet stable pressure differential between the room and outside during ASHRAE-110 Testing.

Contact Info

Although my time at LBNL is over for the summer, that does not mean I am simply leaving and forgetting about the project. In fact, I hope to be kept in the loop regarding the progress of our fume hood and where it goes in the future! If there are any issues, questions, etc. which need to be directed to me, I can be reached at:

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